Research Laboratories

UNITED AIRCRAFT CORPORATION

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D910261-3

RESEARCH INVESTIGATION OF PHASE-REINFORCED

HIGH-TEMPERATURE ALLOYS PRODUCED DIRECTLY FROM A MELT

By

F. D. Lemkey
M. J. Salkind

April 15, 1965

United Aircraft Corporation Research Laboratories
East Hartford, Connecticut

Contract No. DA-19-020-AMC-00434(X)

Boston Procurement District

AMCMS CODE 5025.11.843

Department of the Army Project 1A024401A111

U. S. Army Materials Research Agency
Watertown, Massachusetts 02172

TECHNICAL REPORT NO. AMRA CR-64-05/1

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Reinforced Composites

High-Temperature Alloys

Eutectic Alloys

Unidirectional Solidification

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ABSTRACT

The results of continued investigations on whisker-reinforced high temperature eutectic alloys are presented in this third quarterly report. Ingots of Ta-Ta_2C have been unidirectionally solidified at 15 cm/hr to produce a composite of aligned tantalum carbide rods and platelets within a matrix of tantalum using a modified electron beam zone melting apparatus.

A consistent crystallographic relationship between Ni and NiBe interpenetrating single crystal lamellae of a eutectic grain has been examined in detail using a hard sphere atomistic model of the interface.

The results of a study of cyclically loaded Ni-NiBe eutectic alloy has indicated that most of the deformation takes place within the nickel solid solution matrix. The yield strength increased with each cycle and reached a constant maximum value after four cycles.

Report D910261-3

Research Investigation of Phase-Reinforced

High-Temperature Alloys Produced Directly From a Melt

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INTRODUCTION

This is the third quarterly progress report for Contract No. DA-19-AMC-00434(X) entitled "Research Investigation of Phase-Reinforced High-Temperature Alloys Produced Directly From a Melt," covering the period from 31 December 1964 to 31 March 1965. The principle objective of this research is the production of whisker-reinforced high-temperature alloys directly from the melt by means of unidirectional solidification of eutectic alloys.

This report contains a discussion of results of experimental work carried out during the third quarter and of work to be conducted during the final report period.

EXPERIMENTAL PROCEDURES

Master Heat Production and Controlled Solidification

$Ta-Ta_2C$

A 25 lb master casting which was reprocessed by electron beam melting to bring up the carbon content to that of the eutectic value was re-examined for carbon content and homogeneity. A small amount of primary tantalum carbide was observed along the entire length of the master casting with a greater amount present at the bottom of the ingot. Fabrication of the top 2/3 of the master casting into 1/4 in. rod was then accomplished. Three billets were machined from this master casting and extruded at 2350 F at a 4:1 extrusion ratio. The resulting 1-1/2 in. diameter rod was annealed in argon at 2400 F for two hours and subsequently swaged to 1/4 in. stock at 800 F in several passes each consisting of 10% reduction. A typical analysis of the reprocessed master casting is presented in Table I.

The swaged rods were electron beam zone melted in the MRC apparatus illustrated in Fig. 1. This apparatus, designed primarily to zone refine high temperature materials has been modified to perform unidirectional solidification experiments as shown in Fig. 2. One specimen end clamp has been replaced by a large copper block (F) through which a cooling medium is passed (J). The cooled copper block acts as a heat sink to attain directional heat flow. The presence of the cooled block near the top of the bell jar also acts as a cold trap to lower the total pressure. Since thermal radiation losses are significant whenever high temperatures are involved, the radial loss of energy by radiation must be minimized to arrive at

TABLE I

Composition and Impurity Content of Ta-C Alloy

Master Heat (A65-030)

	Top	Bottom
Al	10 ppm	10 ppm
B	1	1
Cb	86	63
Cd	1	1
Co	5	5
Cr	10	10
Cu	2	2
Fe	15	15
H	3.5	2.4
Mg	10	10
Mn	10	10
Mo	10	10
N	35	40
Ni	10	10
O	160	120
Pb	5	5
Si	10	46
Sr	10	10
Ti	10	10
V	10	10
W	495	530
Zn	10	10
Zr	50	50
C	0.93 wt/o	0.87 wt/o
Ta	Balance	Balance

ELECTRON BEAM FLOATING ZONE SOLIDIFICATION APPARATUS

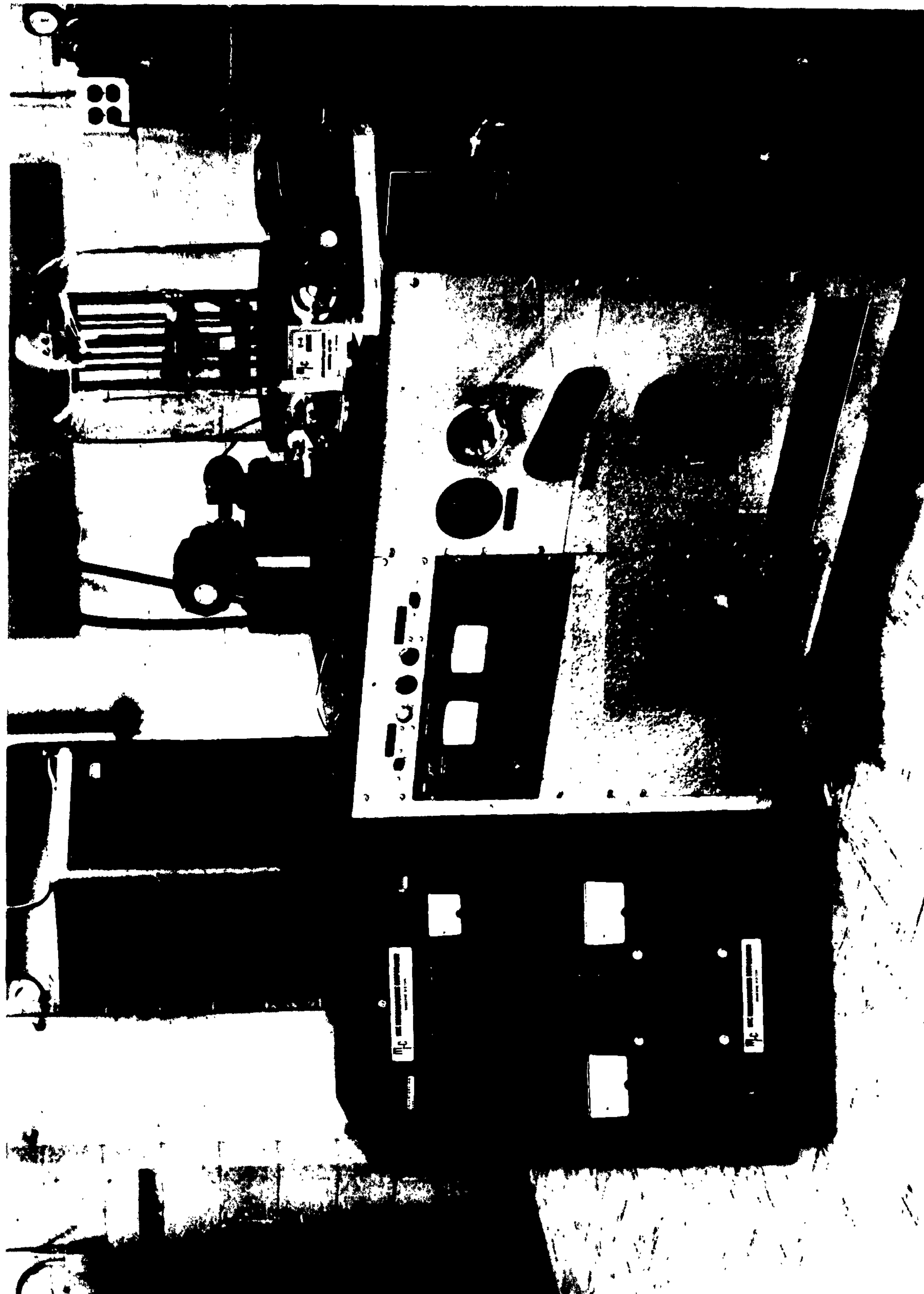
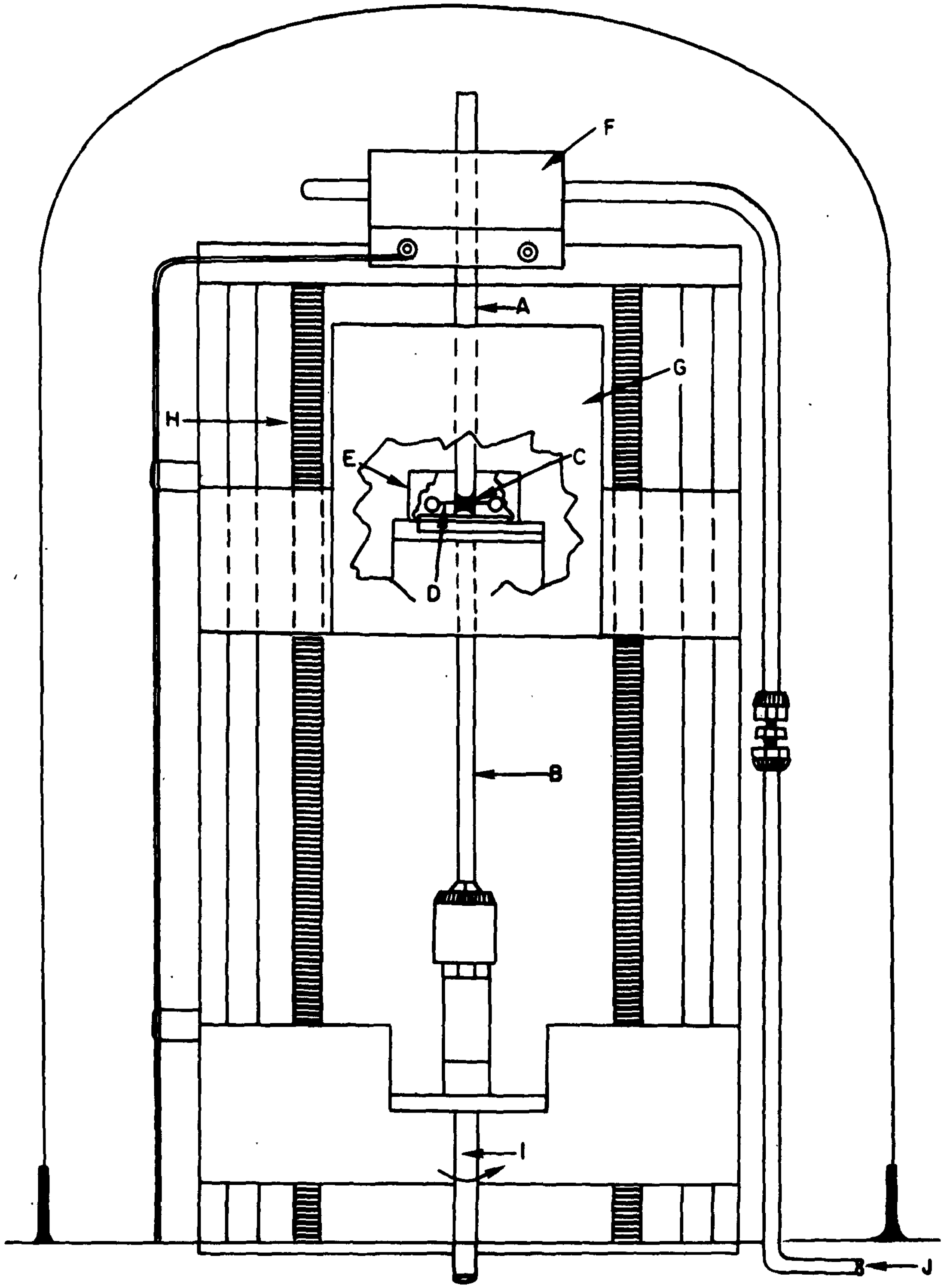


FIG. 2

MODIFIED ZONE SCANNER



A - UPPER HALF OF SPECIMEN
B - LOWER HALF OF SPECIMEN
C - MOLTEN ZONE
D - THERMIONIC EMITTER
E - Mo PILL BOX
F - Cu COOLED BLOCK
G - Ta RADIATION SHIELDS
H - TRANSLATION SCREW
I - SPECIMEN ROTATION DRIVE
J - COOLENT ENTRANCE

the desired directional heat flow constraint. Tantalum sheets (G) in two thicknesses spaced 1/4 in. apart were used to radially shield the thermionic emitter (D) and molybdenum pill box (E). The pill box encloses the emitter and acts as a reflector for electrons. Total enclosure of the filament emitter and pill box was accomplished by shielding the top and bottom of the molten zone (C) with tantalum heat shields (not shown).

The energy required to melt the specimen is provided by the kinetic energy of the electrons, much of which is transformed into thermal energy. The flow of electrons is focused by the geometry of the filament and that of the enclosure. Several filament shapes were employed, including wire and ribbon. Because the wire filament does not close upon itself and allow the electrons to bombard the entire circumference of the specimen, rotational movement of the specimen is necessary for uniform heating of the molten zone. A provision for rotating the lower half of the specimen is located at the bottom specimen clamp and is adjustable from 10 to 200 rpm. Translation of the pill box and filament emitter along the length of the specimen is provided by a screw drive mechanism.

As previously described (Refs. 1 and 2) difficulty was encountered in using a thoriated tungsten wire filament which distorted on heating. A ribbon filament fabricated from thoriated tungsten sheet provided the desired rigidity and also enveloped the entire circumference of the specimen. However, its emission efficiency was low (Ref. 5) and a molten zone at 2800 C could not be attained using the present 2 kw electron beam unit. Currently a thoriated tungsten wire filament is being utilized which is uniformly seated to the electrical leads within a machined seat rather than held in place by two set screws. This has minimized distortion of the emitter when heated.

__Ni-NiBe__

Two eutectic alloy ingots were unidirectionally solidified at 2.1 and 3.3 cm/hr using the same procedure outlined in (Ref. 1). One of the resulting ingots (A65-008) was subsequently machined into a tensile coupon for step loading to failure in tension. A master heat of 50 atom percent Ni and 50 atom percent Be was prepared by consolidating 99.97 Ni rod and 99.7 Be rod and unidirectionally solidifying a 1/2-in. diameter ingot to produce a bulk specimen of NiBe. No effort was made to produce unidirectionally solidified ingots at steeper thermal gradients or at higher solidification rates since this system did not exhibit improvement in properties by unidirectional solidification (Ref. 2).

Crystallography

Ni-NiBe

One grain from the tail end of an ingot solidified at 2.1 cm/hr (A65-008) was analysed by the back reflection precession X-ray diffraction method developed by Kraft (Ref. 3). CoK_α radiation was used in place of FeK_α in order to obtain the separated families of planes for subsequent analysis. Use of CoK_α radiation instead of FeK_α allowed reduction of exposure time from 2 hours to 30 minutes, because the Co tube provided more intense radiation than the iron tube.

Ta-Ta_2C

A Debeye-Scherrer pattern was obtained using CuK_α radiation to identify the carbide particles extracted from a eutectic alloy by an alcoholic bromine solution.

Ni_3B-Ni

Two grains from ingots solidified at 4.7 and 10.7 cm/hr were analysed by the back reflection precession X-ray diffraction method of Kraft (Ref. 3). FeK_α radiation and a specimen to film distance of 1.5 cm were used. The separated families of planes chosen for analysis were the same as those chosen by Shapiro and Ford (Ref. 4). Exposures of two hours duration were required to obtain the desired information for subsequent analysis.

Mechanical Property Evaluation

Ta-Ta_2C

A tensile specimen 0.125-in. diameter with a one inch long gage section was machined from a unidirectionally solidified specimen. The loading was applied parallel to the growth direction using a Tinius Olsen four-screw testing machine at a loading rate of 0.01 inches per minute.

Ni-NiBe

A 0.250-in. diameter, one inch long gage section tensile coupon was ground from a unidirectionally solidified specimen. Parallel flats 0.12 in. wide were ground on opposite sides of the tensile coupon along its length. The specimen was mechanically polished and etched with a solution of one part 20% potassium cyanide

in water and one part 20% ammonium persulfate in H_2O. The specimen was step loaded in the Tinius-Olsen testing machine at intervals of approximately 15,000 psi until considerable yielding occurred and then intervals of approximately 1.5% strain were employed. At the end of each of the nine steps, the polished flat was first examined optically along the gage length for deformation and then replicated at three indexed positions within the gage length for electron microscopic examination. Upon failure the fracture surface was replicated for fractographic analysis. The unidirectionally solidified ingot of NiBe could not be machined into a cylindrical tensile coupon because of grain boundary cracking. However a 1/16 x 1/16 x 1 in. microbend specimen has been machined for four point bend testing.

Ni_3B-Ni

Three specimens 3/4 of an in. long and 1/4 in. in diameter were loaded in compression to failure using a Tinius-Olsen four-screw testing machine at a strain rate of 0.01 in. per minute. A 1/2 in. gage length clip-on compressometer was used to measure strain. The specimen was mounted within a standard Tinius-Olsen compression fixture using flat TiB_2 bearing plates. An alloy steel specimen was used as a standard for calibrating the compressometer. The fractured specimen pieces were mounted in bakelite and mechanically polished and etched for light microscopic examination.

RESULTS AND DISCUSSION

Controlled Solidification

The results of solidification experiments performed during this quarter are presented and discussed below according to eutectic alloy system.

Ta-Ta_2C

Microscopic examination of the top, middle and bottom sections of the reprocessed master alloy indicated only a slight amount of primary carbide located chiefly in the bottom section. The carbon composition of the eutectic microstructure averaged 0.88 by weight which is approximately 10% greater than that previously reported (Ref. 6). The volume percent of Ta_2C within a matrix of Ta present at room temperature under equilibrium cooling conditions was approximately 35% based on this observed eutectic composition.

The results of the unidirectional solidification experiments performed during this quarter are shown in Table II. All of the experiments except that for specimen

TABLE II

Summary Ta-Ta_2C

Unidirectional Solidification Experiments

Identification Number	Charge Number	Traverse Rate (cm/hr)	End Quench	Voltage (kv)	Beam Current (mA)	Filament Current (A)	Vacuum (mm Hg)	Microstructure	Comments
A65-027	A64-047	10	H_2O	2	300	21	2-3 x 10-5	Partial alignment of Ta_2C, L/d 10	Tensile coupon machined 25 rpm end rotation
A65-029	A65-030	10	H_2O	1.4	415	15	2-7 x 10^{-6}	Spheroidized Ta_2C, L/d 1	
A65-031	A65-030	15	H_2O	1.65	360	16	4 x 10^{-5} 1 x 10^{-6}	Partial axial alignment of Ta_2C phase	
A65-032	A65-030	20	H_2O	1.45	390	22	4-7 x 10^{-6}	Small grains "as cast" appearance	
A65-033	A65-030	15	liq N_2	1.5	390	23	1-2 x 10^{-6}	Axial alignment of Ta_2C phase, banded	
A65-034	A65-030	15	liq N_2	1.5	400	12.5	1-3 x 10^{-6}	Partial axial alignment	Top and bottom shields added
A65-035	A65-030	10	liq N_2	1.4	400	14	1-3 x 10^{-6}	Partial axial alignment of Ta_2C	Top and bottom shields added
A65-036	A65-030	10	liq N_2	1.5	400	15	1-2 x 10^{-6}	Partial axial alignment of Ta_2C	Top and bottom shields added
A65-037	A65-030	15	liq N_2	1.5	400	13	1-2 x 10^{-6}	Axial alignment of Ta_2C phase, no bands	Top and bottom shields removed

A65-027 were performed using extruded and swaged alloy. The distribution of the carbide within the tantalum matrix of the starting material is indicated in Fig. 3. The alloy for specimen A65-027 was obtained from the carburizing experiments performed during the first quarter (Ref. 1).

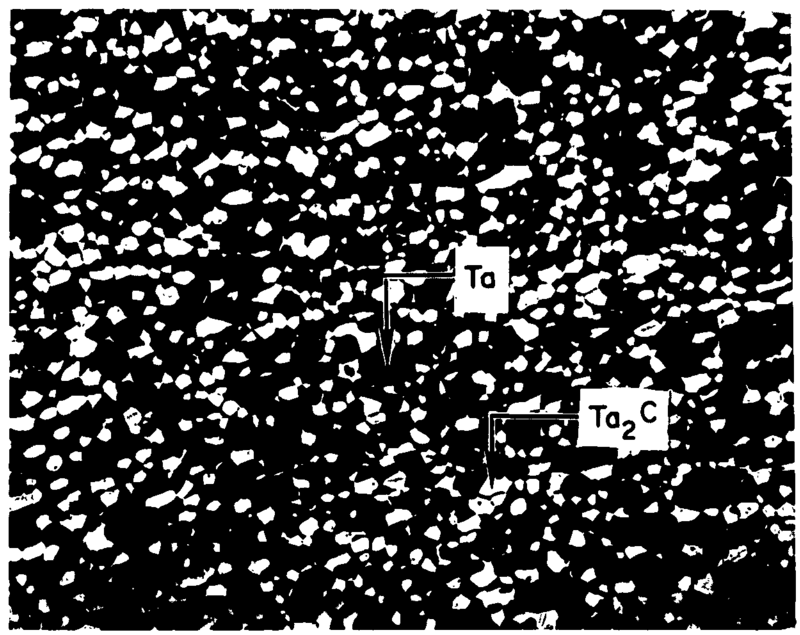
In all the experiments performed to date approximately the same power, 0.6 kw, was required to stabilize a molten zone approximately 5/16 in. long above 2800 C. The first experiments, A65-027 through A65-032, Table II, were performed using water to quench the end of the specimen. Only partial alignment of a small number of eutectic grains parallel to the growth direction was observed at 15 cm/hr. At 10 cm/hr the Ta_2C phase was spherical in shape as determined by metallographic examination using a two surface technique. Increasing the solidification velocity to 20 cm/hr resulted in very small unoriented grains which looked very similar to that of the as-cast alloy. Attempts were made in the next series of experiments to increase the axial heat losses. Specimen A65-033 was solidified using liquid nitrogen at 3 psig to cool the solidified end. This experiment was successful in aligning the Ta_2C phase approximately parallel to the specimen axis. The microstructure produced is illustrated in Fig. 4. The morphology of the Ta_2C phase seems to be primarily ribbon or platelet, however the Ta_2C phase as revealed in some grains sectioned normal to the solidification direction is predominantly rod-like. Alignment of the carbide phase with the solidification direction is clearly evident in the longitudinal section. Banding was also present at irregular intervals which may have been associated with an interruption of liquid nitrogen flow necessary to refill the dewar during this experiment. The aspect ratio of the Ta_2C phase measured on longitudinal sections have exceeded 100 to 1. Aspect ratios thus measured are very conservative since the Ta_2C phase is not necessarily coplanar with the plane of examination.

Further experiments were performed using Ta shielding around the top and bottom of the pill box as well as the sides but were not successful in obtaining the desired directional heat flow. The top and bottom shields were removed and experiment A65-037 was performed. Axial alignment was accomplished without the presence of bands. The flow of liquid nitrogen was uninterrupted in this experiment. Only the last three inches of the six in. long specimen were entirely controlled, however, as evidenced by a longitudinal section taken along the specimens length.

NiBe

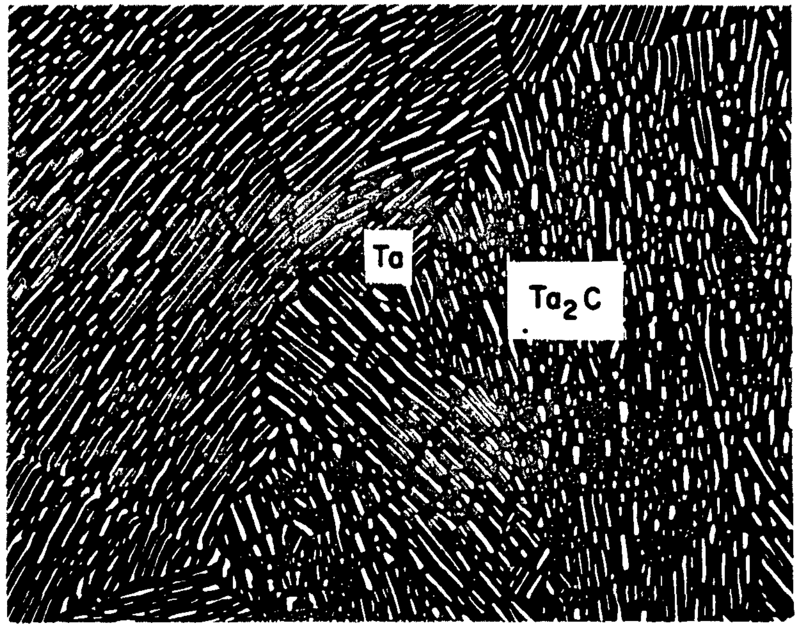
Further work in this system has been discontinued due to the lack of improved properties exhibited by the attainment of aligned NiBe lamellae within a nickel solid solution matrix. To conclude the study of the mechanical behavior, however, two eutectic specimens were unidirectionally solidified at 2.1 and 3.3 cm/hr. The resulting ingots contained a slight amount of primary NiBe phase. In

SWAGED MICROSTRUCTURE OF Ta-Ta_2C EUTECTIC (A65-030)

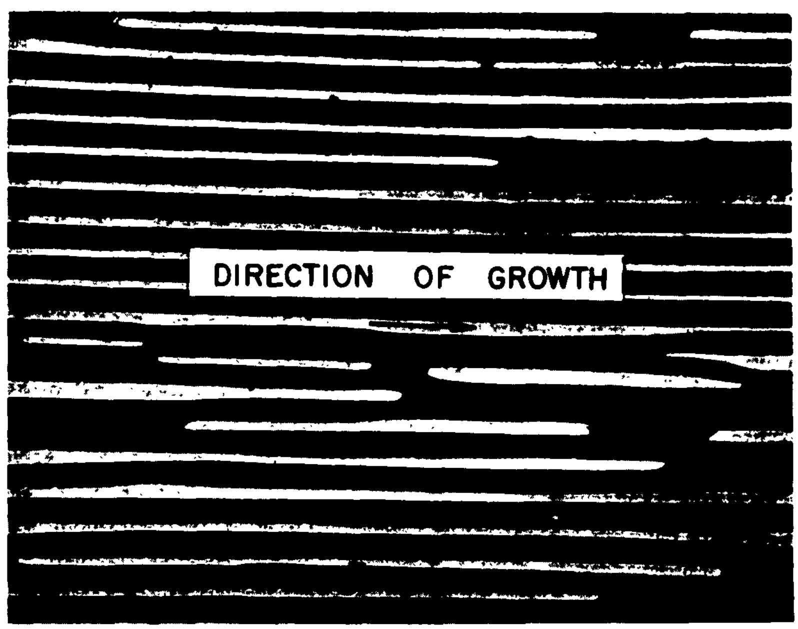


MAGNIFICATION: X200

MICROSTRUCTURE OF Ta-Ta_2C ALLOY (A65-033) UNIDIRECTIONALLY SOLIDIFIED AT 15 CM/HR



TRANSVERSE SECTION: X200, MARGOLIN ENCE ECHANT



LONGITUDINAL SECTION: X1000, MARGOLIN ENCE ECHANT

addition a single ingot of NiBe was produced to determine its mechanical behavior. It was observed on handling and machining that NiBe grain boundaries were extremely weak and failure along these internal surfaces would invariably occur when the specimen was bent or machined.

Crystallography

Ni-NiBe

It has been shown that when a eutectic alloy containing Ni and NiBe is unidirectionally solidified a unique metallographic and crystallographic relationship between the interpenetrating single crystals is found (Ref. 2). This relationship has been summarized as:

$$\text{Interface} \parallel \{111\}_{Ni} \parallel \{110\}_{NiBe}$$

$$\langle 110\rangle_{Ni} \parallel \langle 111\rangle_{NiBe}$$

Further experimental confirmation of this relationship has been determined for another eutectic grain solidified at 2.1 cm/hr. This orientation is unique in that the close packed planes and the close packed directions in each phase are parallel to each other and to the metallographic interface. Since these are the planes of densest atomic packing, this observation supports the idea that the interfaces in unidirectionally solidified eutectics will consist of stable low energy planes (Ref. 7).

This unique orientation existing between B.C.C. and F.C.C. phases in equilibrium has been shown to exist for at least two other systems. Smith and Mehl (Ref. 8) have shown that the close packed planes and directions are parallel for austenite (F.C.C.) and ferrite (B.C.C.) in steel. In addition, Speich and Oriani (Ref. 9) have recently found a similar relationship for copper precipitates in an alpha iron matrix.

To examine the registry of the coincident phases in greater detail, constructions of the atom positions on the octahedral planes of nickel and the $\{110\}$ planes of NiBe were made (Figs. 5 and 6). The similarities in atomic positions and triangular symmetry can be readily observed. It can be assumed that the strain energy associated with this interface is low.

FIG. 5

Ni {111} PROJECTION OF ATOM POSITIONS

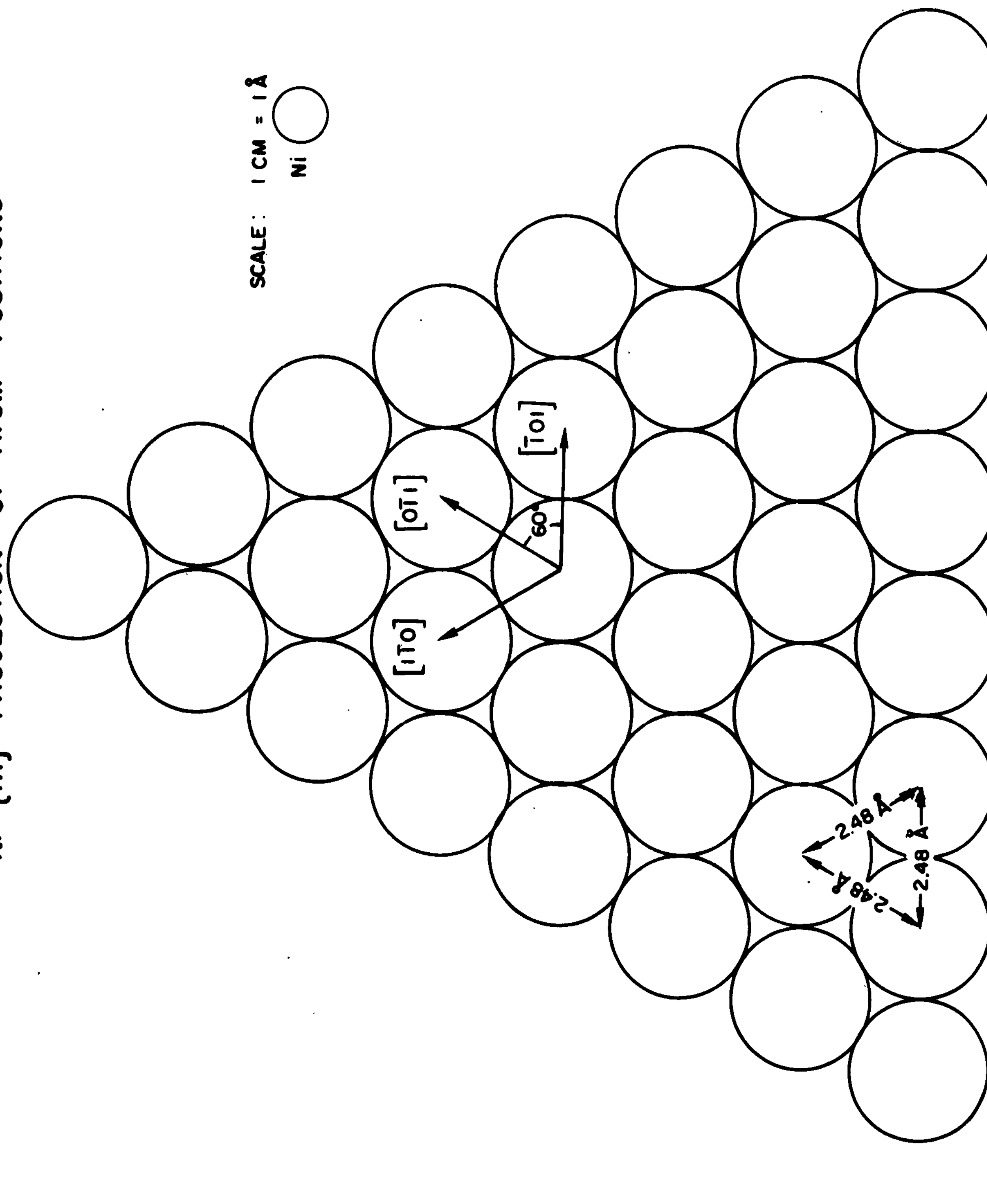
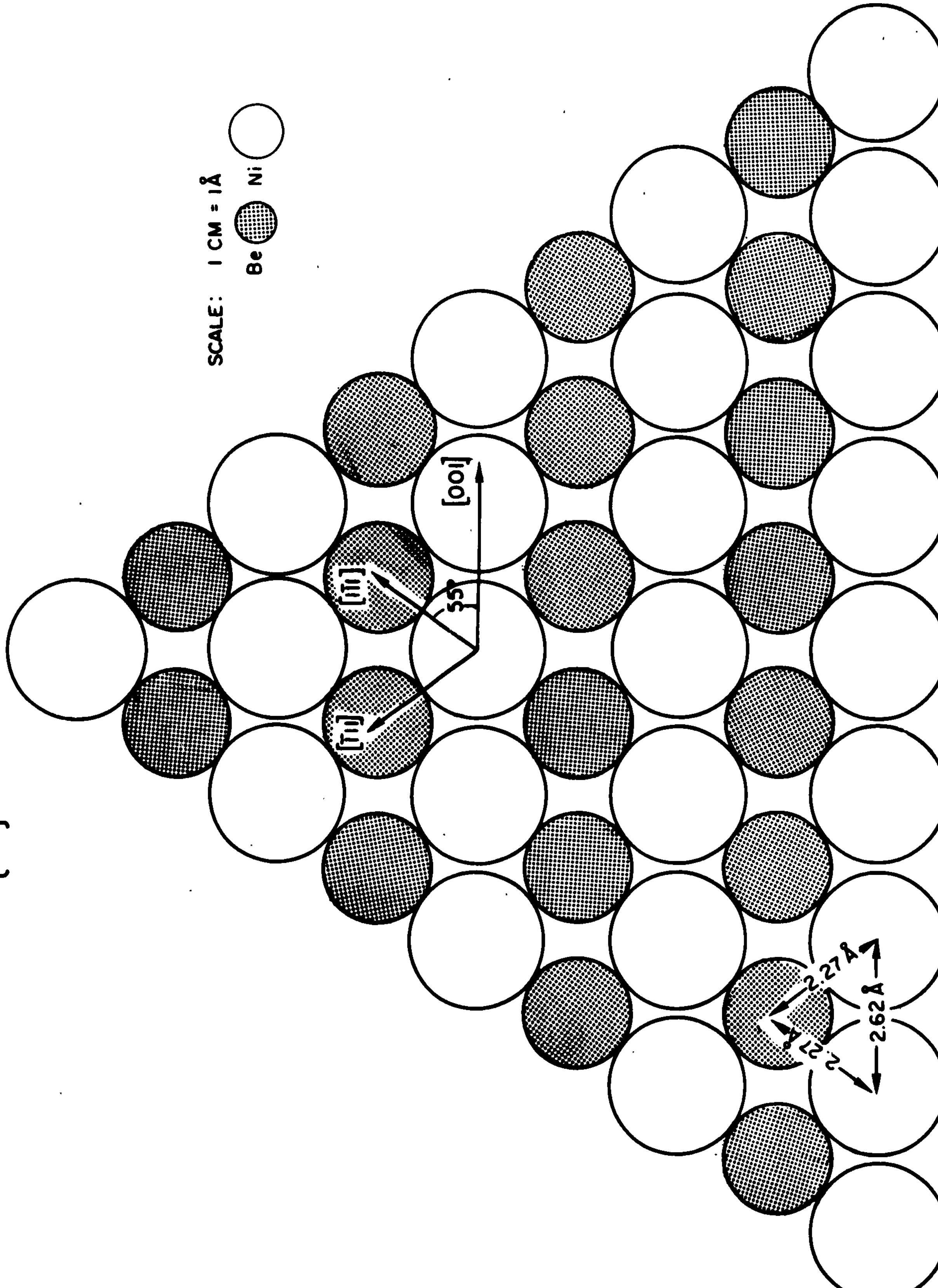


FIG. 6

NiBe {110} PROJECTION OF ATOM POSITIONS



Ni_3B-Ni

Two eutectic grains from specimens solidified at 4.7 and 10.7 cm/hr exhibited substructure which resulted in considerable broadening in the X-ray diffraction pattern. This broadening precluded determination of the crystallographic relationships between the two phases. The substructure consists of areas of angular misorientation between Ni_3B and Ni platelets. The areas which are free of substructure are too small to be examined by present X-ray diffraction techniques.

Ta-Ta_2C

Since the existence of a new hexagonal tantalum carbide phase has recently been determined by Villagrana and Thomas (Ref. 10) 1965, a confirmatory check was made on the existence of Ta_2C. The results of a Debeye-Scherrer pattern on the extracted tantalum carbide phase are presented in Table III. Positive identification of hexagonal Ta_2C being the only phase present confirms the phase equilibrium diagram (Ref. 6) for the system Ta-C.

Mechanical Property Evaluation

Ta-Ta_2C

The stress-strain behavior of a unidirectionally solidified specimen (A65-027), the whisker aspect ratio for which was found to vary from 1 to 10 as measured by longitudinal sectioning, is presented in Fig. 7. The increase in ultimate tensile strength and corresponding decrease in total elongation compared with that for a specimen containing a random carbide dispersion (Ref. 1) indicate that some fiber reinforcement is obtained even for the relatively small aspect ratio. A longitudinal section through the fracture surface is shown in Fig. 8. No break-up of the Ta_2C phase is observed.

Ni-NiBe

As reported previously the results of tensile tests on specimens machined from unidirectionally solidified Ni-NiBe alloy indicate that strength enhancement by second phase reinforcement has not been achieved. An interesting phenomena was observed during the testing of this alloy in tension. Surface cracks formed along the gage length of the specimen but did not propagate through the sample although the stress concentration was high. Several of these cracks can be seen in Fig. 9 which is a longitudinal section of a specimen which was strained to failure with a total strain at failure of 9.4%.

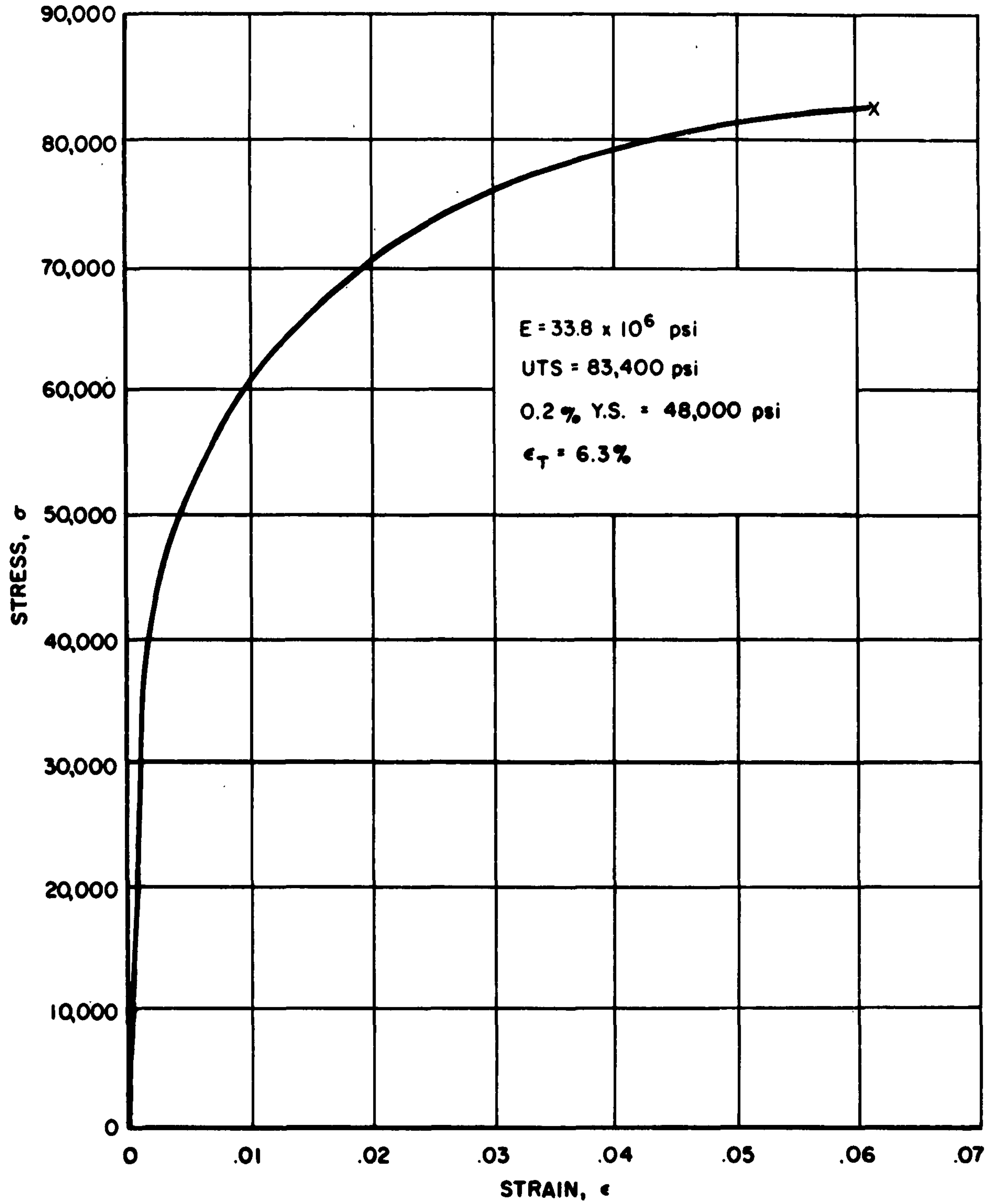
TABLE III

Powder Pattern Data on Extracted Tantalum Carbide

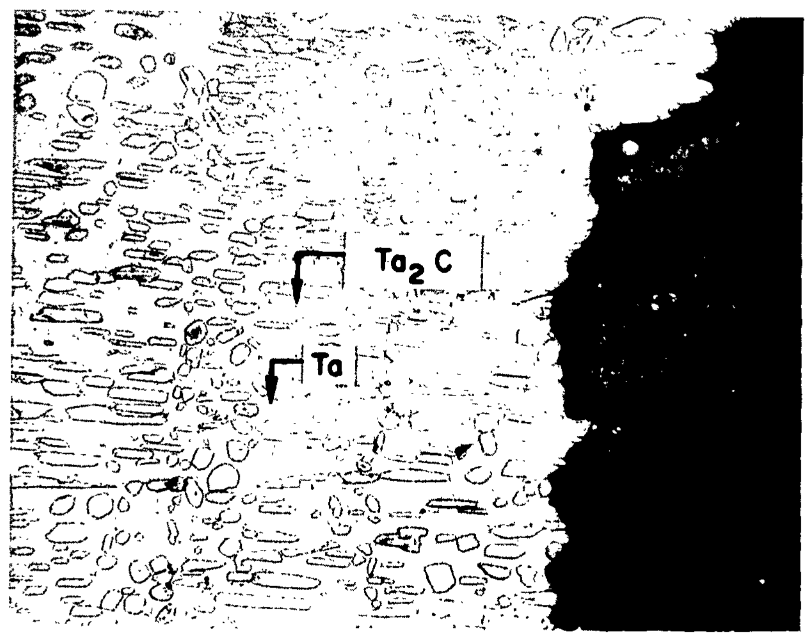
Phase from Ta - 0.8 wt/o C Eutectic Alloy

Line	Diff. Angle θ Rad	Rel. Intensity I/I_1	$\sin^2\theta$	Calculated $\sin^2\theta$	Indices hkl
1	16.71	60	.0827	.0823	100
2	18.21	100	.0977	.0977	002
3	19.11	100	.1072	.1067	101
4	25.11	80	.1800	.1800	102
5	29.83	70	.2475	.2470	110
6	33.36	90	.3024	.3022	103
7	35.04	10	.3297	.3293	200
8	35.99	80	.3453	.3447	112
9	36.51	40	.3540	.3537	201
10	38.69	50	.3907	.3909	004
11	40.84	20	.4277	.4270	202
12	43.46	40	.4731	.4732	104
13	47.84	40	.5495	.5492	203
14	49.42	20	.5768	.5762	210
15 α_1	50.79	50	.6003	.5996	211
15 α_2		30			
16 α_1	52.89	50	.6359	.6359	114
16 α_2		30			
17 α_1	55.14	30	.6733	.6727	212
17 α_2		10			
18 α_1	56.22	60	.6908	.6907	105
18 α_2		40			
19 α_1	57.92	20	.7179	.7181	204
19 α_2		1			
20 α_1	59.32	20	.7376	.7396	300
20 α_2	59.62	1	.7442		
21 α_1	63.02	60	.7942	.7944	213
21 α_2	63.29	40	.7980		
22 α_1	66.22	30	.8375	.8370	302
22 α_2	66.54	10	.8415		
23 α_1	69.40	50	.8762	.8762	006
23 α_2	69.77	30	.8804		
24 α_1	75.47	60	.9376	.9372	205
24 α_2	76.07	40	.9420		
25 α_1	78.17	60	.9580	.9584	106
25 α_2	78.77	40			
26 α_1	79.17	50	.9647	.9647	214
26 α_2	79.90	30	.9692		
27 α_1	83.25	50	.9862	.9862	220
27 α_2	84.63	30	.9912		

STRESS - STRAIN BEHAVIOR OF UNIDIRECTIONALLY SOLIDIFIED $Ta - Ta_2C$ ALLOY (A65-027)



FRACTURE BEHAVIOR IN $Ta-Ta_2C$ EUTECTIC ALLOY (A65-027)



MAGNIFICATION: 1000 X

SURFACE CRACKS DEVELOPED IN TENSION LOADED Ni - NiBe ALLOY SPECIMENS

SPECIMEN STRAINED 9.4%
MAGNIFICATION: X500

The phenomenon of crack arrest and the micromechanics of deformation were studied in more detail by a cyclic loading experiment. The specimen was examined after predetermined increments of strain. The stress-strain behavior during a tensile test consisting of 9 loading increments is shown in Fig. 10. The specimen contained a slight amount of primary NiBe. Slip lines were first observed in the Ni phase after 0.6% elongation. After successive loadings, slip bands in the matrix became pronounced and severe plastic deformation near primary NiBe phase particles was noted. After the sample ruptured (7.3% elongation) light microscopic studies of longitudinal sections revealed cracks originating from the Ni-proeutectic particles and propagating into the lamellar eutectic region. These cracks generally traveled in a direction normal to the solidification direction. In a few instances when the cracks propagated parallel to the direction of applied stress interlamellar decohesion was noted. In no case was any deformation seen within the NiBe phase. The interaction of slip in the nickel solid solution matrix with the discontinuous NiBe lamellae is seen in Fig. 11. This specimen underwent 9 loading cycles. It appears that most of the deformation occurs in the matrix.

The changes in stress-strain behavior brought about by previous loading cycles were investigated. It was found that the yield stress increased during the first few cycles and then remained constant during the subsequent loading cycles. This behavior can be seen in Fig. 12 which indicates the variation in yield strength with the number of loading cycles. Similar behavior has been observed for aluminum (Ref. 11) and Udimet 600 (Ref. 12).

Ni_3B-Ni

The results of compression tests on unidirectionally solidified lamellar Ni_3B-Ni eutectic specimens loaded parallel to the growth direction are shown in Table IV. The elastic modulus in compression agreed with that determined in tension (Ref. 2). Since the fracture was catastrophic the compressometer detached at a stress level of approximately 100,000 psi. In two cases the cylindrical specimen failed by splitting in half.

The fracture path as observed in a section perpendicular to the load axis is shown in Fig. 13. Fracture propagated in the Ni_3B matrix and appeared to be deflected by the change in orientation of the Ni plates. No evidence of interfacial decohesion was noted.

INTERRUPTED TENSILE TEST ON Ni-NiBe ALLOY (A65-008) SHOWING CHANGE IN DEFORMATION CHARACTERISTICS DURING CYCLIC LOADING

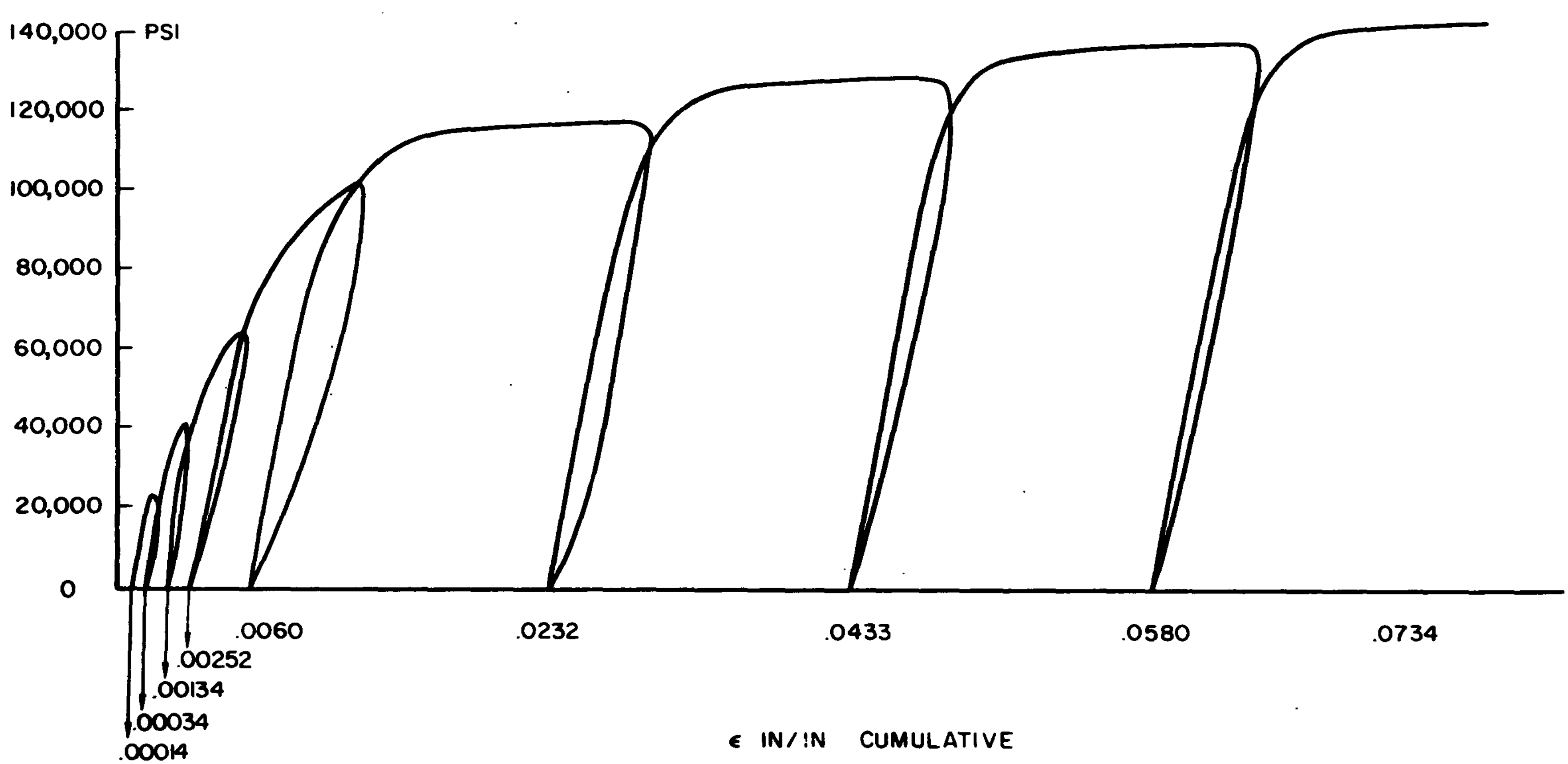


FIG. 10

SLIP LINES IN Ni-NiBe ALLOY (A65-008) STRESSED TO FAILURE

Ni

NiBe

STRESS DIRECTION PARALLEL TO PLATELETS
MAGNIFICATION: X5000

YIELD STRENGTH LIMIT DUE TO CYCLIC LOADING

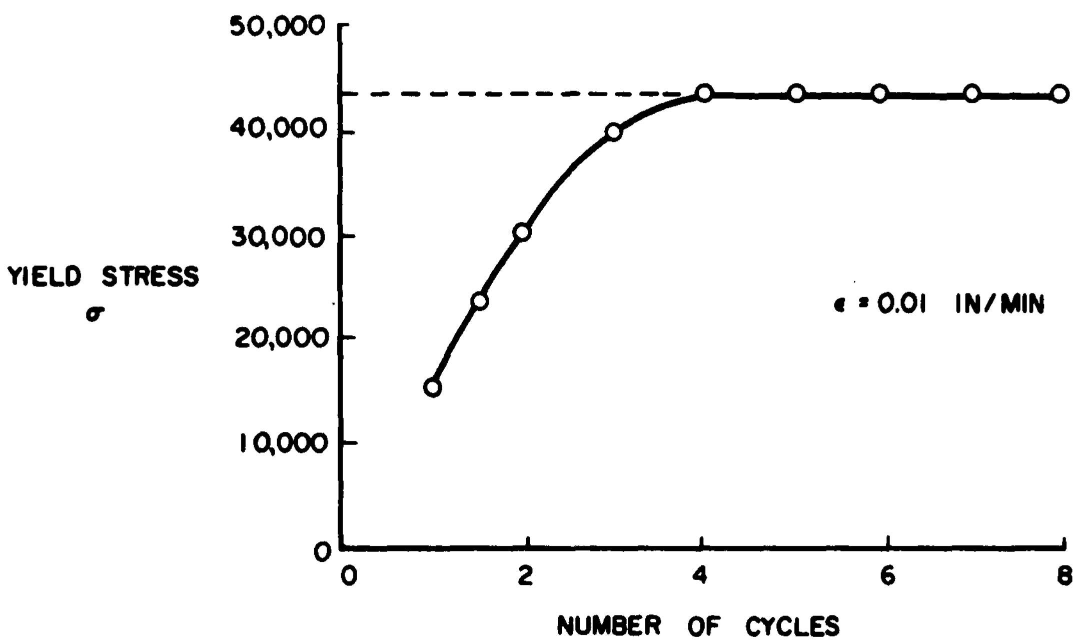


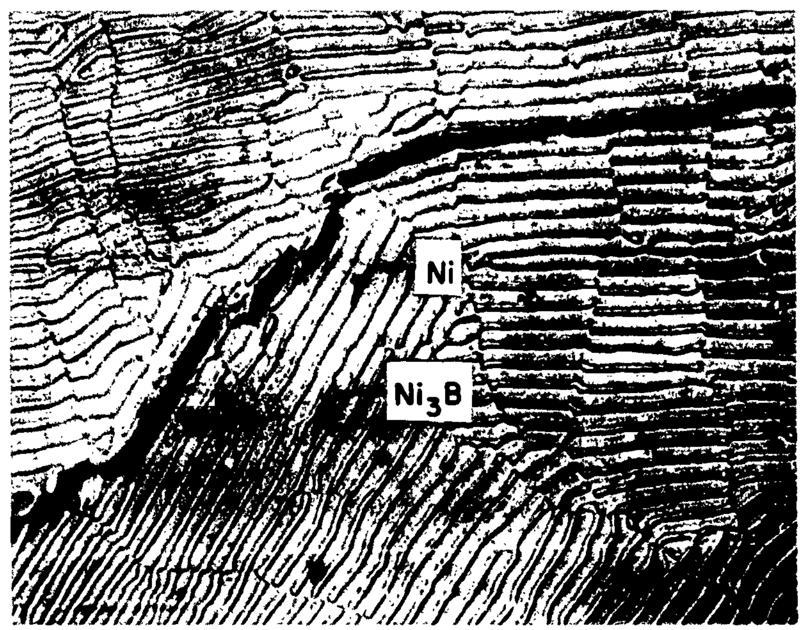
TABLE IV

Summary of Compression Tests Ni_3B-Ni

Traverse Rate R cm/hr	Sample	Diameter (in.)	Area (in.^{2})	Length (in.)	Ultimate Load (lbs)	Ultimate Compressive Strength (psi)	Loading Rate (in/min)	Elastic Modulus (psi)	Strain* ϵ %	Failure
5.3	A64-371-02	0.2496	0.04890	0.750	14,000	286,000	0.01	---	0.86	Brittle
4.7	A64-401-2	0.2496	0.04890	0.748	12,500	256,000	0.01	34.0×10^6	0.77	Brittle
4.7	A64-401-4	0.2494	0.04883	0.749	12,950	265,000	0.01	31.0×10^6	0.80	Brittle

* Total strain based on Hookean behavior to failure $E = 33 \times 10^6$ psi

FRACTURE AND CRACK PATH THROUGH Ni_3B PLATELETS (A64-401)



MAGNIFICATION: 1000 X

FUTURE WORK

During the final report period continued efforts will be made to produce controlled microstructures in the Ta-Ta_2C eutectic system over a range of solidification velocities. In addition, an alloy of nickel beryllium solid solution will be prepared in order to evaluate its mechanical behavior.

X-ray crystallographic examination will be performed on single grains of Ta-Ta_2C. Tensile testing of specimens machined from controlled Ta-Ta_2C ingots to determine their strength and deformation characteristics will be continued.

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F. D. Lemkey and M. J. Salkind
United Aircraft Corporation Research Laboratories, East Hartford, Connecticut

Report No. AMRA CR-64-05/1, Apr. 1965, 33 pp - tables - illus., (Contract DA-19-020-AMC-00434(X)), DA Project 1A024401A111, Unclassified Report

The results of continued investigations on whisker-reinforced high-temperature eutectic alloys are presented in this third quarterly report. Ingots of $Ta-Ta_2C$ have been undirectionally solidified at 15 cm/hr to produce a composite of aligned tantalum carbide rods and platelets within a matrix of tantalum using a modified electron beam zone melting apparatus.

A consistent crystallographic relationship between Ni and NiBe interpenetrating single crystal lamellae of a eutectic grain has been examined in detail using a hard sphere atomistic model of the interface.

The results of a study of cyclically loaded Ni-NiBe eutectic alloy has indicated that most of the deformation takes place within the nickel solid solution matrix. The yield strength increased with each cycle and reached a constant maximum value after four cycles.

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